Standard Operating Procedure for Cardiac Auscultation in Children with Congenital Heart Disease

Discussion Draft — English version

Applicable setting: the cardiac auscultation component of community- and school-based mass screening for pre-school and school-age children.

Target audience: auscultating physicians and nurses, screening team leaders, and quality-control personnel.

Core objective: to ensure the sensitivity and consistency of cardiac auscultation as a first-line screening method, through standardised training and on-site quality control.

Basis for development: the National Health Commission Protocol for Neonatal Screening for Congenital Heart Disease (Guo Wei Fu You You Bian Han [2018] No. 68), and eight years of practical screening experience covering more than 6.3 million children in Yunnan Province.

Contents

- Chapter 1 Personnel Training
- Chapter 2 Content Assessment
- Chapter 3 Training Quality Control
- Chapter 4 Standard On-Site Auscultation Procedure
- Chapter 5 On-Site Quality Control
- Appendices

Chapter 1 Personnel Training

1.1 Training Participants and Admission Criteria

(1) Training Participants

Category of Participant	Description
First-time trainee (physician)	Clinicians participating in screening for congenital heart disease (CHD) in children for the first time; must complete all training modules and pass the assessment.
First-time trainee (nursing)	Nursing staff with clinical experience in paediatrics or cardiology; must complete all training modules and pass the assessment.
Refresher trainee	Individuals who already hold certification but whose annual auscultation volume is below standard, or who failed the annual assessment.
Visiting trainee	Physicians or nurses from primary-level healthcare institutions who plan to carry out screening locally.

(2) Admission Criteria

Applicants for auscultation training must satisfy the corresponding requirements below:

Physician pathway:

1. Hold a valid *Physician Qualification Certificate* and *Physician Practice Certificate*.

2. Practice scope registered in internal medicine, paediatrics, cardiovascular medicine, general practice, or a related specialty.
3. At least 1 year of clinical work experience.

Nursing pathway:

1. Hold a valid *Nurse Practice Certificate*.
2. At least 2 years of nursing experience in paediatrics, cardiology, or emergency medicine.
3. Recommendation by the applicant's department, and a basic foundation in cardiac auscultation (e.g. prior participation in cardiac ward rounds or electrocardiographic monitoring).

Common requirements:

- Proficiency in using a stethoscope to perform cardiac auscultation in adults or children.

1.2 Training Content

Training comprises three stages: **theoretical instruction → simulation training → on-site hands-on practice**.

Stage 1: Theoretical Instruction (no fewer than 8 class hours)

Module	Content	Hours
Epidemiology and pathological basis of CHD	Epidemiological data on CHD in China (prevalence 4.9 per 1,000); pathophysiology and haemodynamic changes of common CHDs (ASD / VSD / PDA / TOF / PS); the natural history of CHD and the significance of early intervention.	2
Fundamentals of paediatric cardiac auscultation	Mechanisms and auscultatory characteristics of the normal heart sounds (S1, S2); the standard five-area auscultation sequence and the normal findings at each valve area; differences between paediatric and adult heart sounds (faster heart rate; innocent murmurs are common).	2
Recognition of pathological murmurs	Detailed exposition of the Levine six-grade classification; characteristics and differentiation of systolic, diastolic, and continuous murmurs; auscultatory features of common CHDs (harsh holosystolic murmur of VSD; systolic ejection murmur with fixed splitting of S2 in ASD; continuous machinery murmur of PDA; systolic ejection murmur with a single S2 in TOF; differentiation from the innocent Still's murmur).	3
Interpretation of positive findings and management workflow	Criteria for a positive result (systolic murmur ≥ grade 2/6; diastolic or continuous murmur of any grade; abnormal S2); scripts for guiding and communicating with screen-positive children; case analysis of common missed and incorrect diagnoses.	1

Stage 2: Simulation Training (no fewer than 4 class hours)

Module	Content	Hours
Heart-sound simulator training	Use electronic heart-sound simulators or high-fidelity heart-sound recordings to train recognition of normal heart sounds, the various pathological murmurs, and splitting of S2. Required identification accuracy ≥ 85%.	2
Standardised patients / role play	Simulated on-site screening scenarios: variation in the child's cooperation, auscultation in a noisy environment, and guidance of screen-positive children. Trainers play the volunteers and the children being examined.	1

Module	Content	Hours
Case interpretation training	Twenty standardised audio/video cases are provided (several cases each of normal findings, VSD, ASD, PDA, TOF, PS, and innocent murmurs); trainees interpret the cases independently and write auscultation reports.	1

Stage 3: On-Site Hands-On Practice (no fewer than 2 screening days)

Module	Content	Requirement
Supervised auscultation	On-site auscultation performed under the one-to-one supervision of a trainer; each trainee independently completes auscultation and interpretation for ≥ 200 children.	The trainer gives immediate feedback and corrects auscultation technique.
Verification against echocardiography	After the trainee's auscultation, an ultrasound physician performs echocardiography on the same child, and the auscultatory interpretation is compared with the ultrasound diagnosis.	An auscultation–ultrasound comparison log is maintained, with a cumulative total of ≥ 50 comparisons.
Follow-up of positive cases	For every case the trainee interprets as positive, the echocardiographic confirmatory result is tracked in full, and an individual "auscultation–confirmed diagnosis" file is established.	Individual sensitivity data are recorded.

1.3 Minimum Hands-On Threshold for Training

Trainees must complete, cumulatively, no fewer than **50** paired records comparing auscultation findings with echocardiographic results during the training period; this is a mandatory condition for passing the training assessment. Trainees who do not reach this minimum sample size are not eligible to sit the formal assessment.

1.4 Requirements for Training Faculty

Type of Faculty	Qualification Requirements
Theory lecturer	A cardiologist or paediatrician holding the title of associate chief physician or above, or a nurse who has been engaged in the diagnosis and treatment of CHD for ≥ 5 years.
Skills preceptor	Annual auscultation volume ≥ 2,000 children and ≥ 2 years of participation in CHD screening work.
Simulation training instructor	Has completed unified training and certification, and is proficient in operating the heart-sound simulator and in standardised teaching methods.

Chapter 2 Content Assessment

2.1 Structure of the Assessment System

The assessment adopts a three-dimensional evaluation of **"theory + skills + on-site performance"**; auscultation certification is granted only when all three components are passed:

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Theory assessment (computer-based / written examination)
            |
Skills assessment (simulator + case interpretation)
            |
On-site assessment (≥ 200 independent auscultations + quality review)
            |
Overall evaluation → Pass / Fail / Retake within a prescribed period
```

2.2 Theory Assessment

Item	Requirement
Format	Closed-book written examination or computer-based examination.
Question types	Single-answer questions (60%) + multiple-answer questions (20%) + case-analysis questions (20%).
Number of questions	80 questions; maximum score 100.
Pass mark	≥ 80 points.
Retake	Candidates who fail may take one retake within 1 month; those who fail again must repeat the training.

Knowledge coverage requirements:

Knowledge Domain	Weight	Minimum Correct Rate
Epidemiology and pathological basis of CHD	15%	≥ 70%
Normal heart sounds and innocent murmurs	20%	≥ 80%
Recognition of pathological murmurs	35%	≥ 80%
Levine grading and interpretation criteria	20%	≥ 80%
Management of positive findings and communication	10%	≥ 70%

2.3 Skills Assessment

(1) Simulator-Based Auscultation Assessment

Item	Requirement
Test content	Thirty heart-sound segments are drawn at random from a standardised item bank (including normal heart sounds, the various CHD murmurs, and innocent murmurs).
Pass criteria	Correct identification rate ≥ 85% (number correct / 30 ≥ 26).
Special requirements	Detection rate (sensitivity) for pathological murmurs ≥ 90%; no case of critical congenital heart disease (CCHD) may be missed.

2.4 On-Site Assessment

Item	Requirement
Number of independent auscultations	≥ 200 cases, completed under the on-site supervision of a trainer.
Auscultation–echocardiography comparison	A cumulative record of ≥ 50 comparisons between the trainee's auscultation findings and echocardiographic results. This is the minimum hands-on threshold for passing the training (a mandatory indicator; trainees who do not meet it may not sit the assessment).
Individual sensitivity	≥ 90% (number of cases in which the trainee's auscultation was positive and echocardiography confirmed a positive finding ÷ total number of cases confirmed positive by echocardiography).
Guidance of positive cases	Trainer's observational score ≥ 80 (out of 100), covering communication scripts, guidance of the child, and accuracy of marking.

2.5 Categories of Assessment Outcome

Grade	Standard	Action
Grade A (Excellent)	Theory ≥ 90 + skills ≥ 90% + individual sensitivity ≥ 95%	Auscultation certification granted; may independently undertake auscultation work.
Grade B (Qualified)	Theory ≥ 80 + skills ≥ 85% + individual sensitivity ≥ 90%	Auscultation certification granted; advised to work under the guidance of a senior physician for the first 3 months.
Grade C (Retake required)	Any one component fails to reach the Grade B standard, but theory ≥ 70 + skills ≥ 70% + individual sensitivity ≥ 80%	Retake within 1 month; if the retake is again failed, training must be repeated.
Grade D (Unqualified)	Theory < 70, or skills < 70%, or individual sensitivity < 80%, or a missed CCHD case	Repeat the full training programme.

Chapter 3 Training Quality Control

3.1 Standardisation of the Training System

(1) Standardised teaching materials

- This SOP and the accompanying training materials shall be used uniformly.
- The heart-sound simulator recording library is updated every 2 years to incorporate the most recent typical and difficult cases.
- The theory examination item bank is reviewed and approved by the provincial expert panel, with ≥ 20% of the items renewed each year.

(2) Certification of trainers

- Trainers must pass the provincial trainer certification examination (theory ≥ 95 points + teaching demonstration score ≥ 85 points).
- Recertification every 3 years.
- Each trainer supervises no more than 20 trainees per year.

3.2 Monitoring Indicators for the Training Process

Monitoring Indicator	Target Value	Monitoring Frequency
Trainee attendance rate	100%	Every class hour
Trainer teaching evaluation score	≥ 90 points	At the end of each training course
Trainee satisfaction	≥ 85%	At the end of each training course
First-attempt pass rate	≥ 80%	At the end of each training course
Retake pass rate	≥ 90%	After the retake

3.3 Follow-Up of Training Outcomes

(1) Follow-up 3 months after taking up the post

Indicator	Standard
Number of independent auscultations	≥ 1,500 cases
Consistency on on-site quality-control spot checks	≥ 90%
Missed-diagnosis events	0 missed CCHD cases

(2) Annual refresher training

- No fewer than 4 class hours of auscultation-specific continuing education each year.
- Participation in ≥ 2 case conferences on difficult or misdiagnosed cases.
- Those whose annual auscultation volume falls below 500 cases must retake the skills assessment.

(3) Certification management

- Auscultation certification is valid for 3 years.
- On expiry, renewal requires passing a re-review assessment (theory + skills).

- Those whose consistency on the annual quality-control spot check is < 85% shall have their certification suspended and must undergo retraining.

Chapter 4 Standard On-Site Auscultation Procedure

4.1 Preparation Before Auscultation

(1) Environment

- The auscultation area must be quiet and free of interference (away from loudspeakers, construction work, and traffic noise).
- If outdoors, give preference to a sheltered, shaded location.

(2) Positioning

- The child is seated or lying supine.
- The physician sits facing the child (not to the side), keeping their gaze level with the child's.
- The anterior chest is fully exposed while taking care to keep the child warm.

(3) Stethoscope

- Use a high-quality stethoscope (dual-head chestpiece with diaphragm and bell).
- Use the diaphragm for high-frequency sounds (murmurs) and the bell for low-frequency sounds (S3, S4, and diastolic rumbles).
- Warm the chestpiece in the palm of the hand before auscultation.
- Orient the ear-tips forward, in line with the direction of the external auditory canal.

4.2 Standard Auscultation Sequence

The **"area-by-area sequential method"** is adopted (recommended, and applied uniformly across the team):

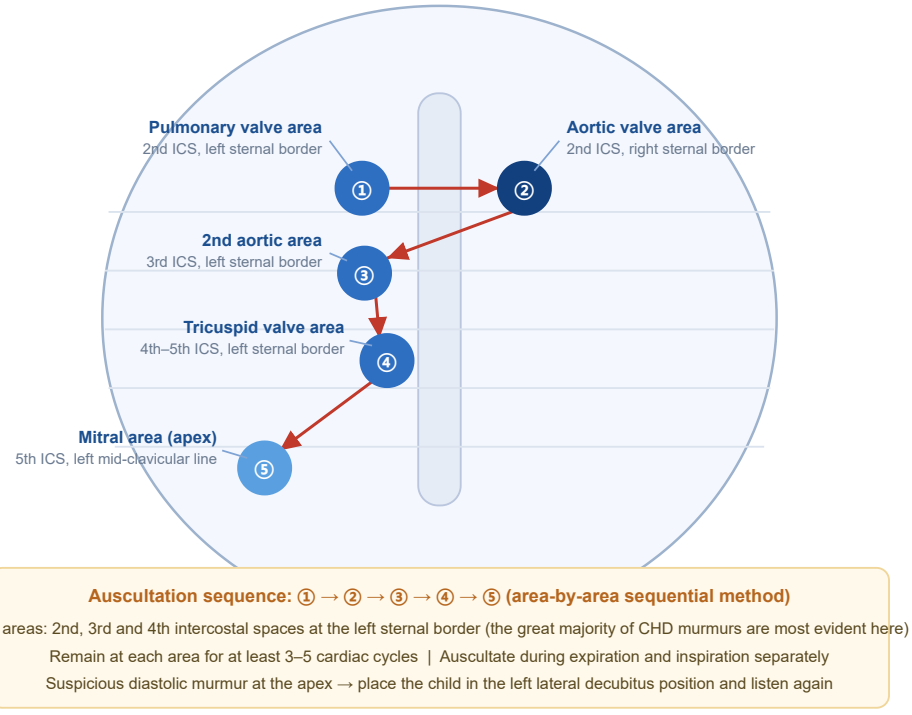

Figure 4-1 Schematic diagram of the five cardiac valve auscultation areas (area-by-area sequential method, ① → ② → ③ → ④ → ⑤)

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Pulmonary valve area — 2nd intercostal space, left sternal border   ← area where CHD murmurs are most
often heard
        ↓
Aortic valve area — 2nd intercostal space, right sternal border
        ↓
Second aortic auscultation area — 3rd intercostal space, left sternal border
        ↓
Tricuspid valve area — 4th and 5th intercostal spaces, left sternal border
        ↓
Apex (mitral valve area) — 5th intercostal space, left mid-clavicular line
```

Key principles:

- Remain at each auscultation area for at least 3–5 cardiac cycles.
- During those few seconds of auscultation, shut out surrounding interference and concentrate completely; it is essential to hold one's breath and listen intently, so as to "converse" with the sounds of the heart.
- Auscultate during expiration and inspiration separately (some murmurs are clearer on expiration).
- The 2nd, 3rd, and 4th intercostal spaces at the left sternal border are the key areas (the great majority of CHD murmurs are most evident here).
- If a suspicious diastolic murmur is detected at the apex, place the child in the left lateral decubitus position and listen again.

4.3 Murmur Grading and Interpretation Criteria

The Levine six-grade classification is used:

Grade	Characteristics	Interpretation
1/6	Extremely faint; audible only on careful listening	Negative
2/6	Soft, but audible as soon as the stethoscope is applied	Positive
3/6	Moderate intensity, without a thrill	Positive
4/6	Loud murmur, accompanied by a thrill	Positive
5/6	Very loud; still audible with one edge of the stethoscope off the chest wall	Positive
6/6	Extremely loud; still audible with the stethoscope entirely off the chest wall	Positive

Interpretation rules:

1. Systolic murmur of ≥ grade 2/6 → judged screen-positive; guide the child to the echocardiography area.
2. Extremely faint murmur of grade 1/6 → judge in combination with the physical examination; if there are no other abnormal signs, it may be marked screen-negative.
3. Diastolic murmur (of any grade) → always judged screen-positive.
4. Continuous murmur (systolic + diastolic) → always judged screen-positive.
5. Abnormal second heart sound (fixed splitting; a single, loud or soft S2; paradoxical splitting) → judged screen-positive.

4.4 Workflow for Managing Screen-Positive Children

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Auscultation judged positive
    │
    ├── The physician signals to the volunteer (without announcing “there is a problem” in front of the child)
    │
    ├── The volunteer guides the child gently: “Hello there, we are going to do one more, more careful check — it will be quick.”
    │
    ├── A temporary mark is made on the back of the child’s hand or on the wrist
    │
    ├── The volunteer accompanies and escorts the child throughout to the echocardiography waiting area
    │
    └── Screen-positive children are prevented from wandering off or from joining the queue of children already screened negative
```

Documentation requirements: immediately after each child has been auscultated, the following must be recorded in the register:

- Auscultation result: negative / positive.
- For positive cases: murmur grade, site of maximum intensity, and character of the murmur (systolic / diastolic / continuous).
- Signature of the auscultating physician and the time.

4.5 Special Precautions

Point of Attention	Explanation
Differentiation of innocent murmurs	Still’s murmur (soft, musical, at the mid-to-lower left sternal border, early-to-mid systolic, grade 1–2/6) is a normal variant and should not be judged positive.
Febrile children	Fever accelerates the blood flow and may produce a functional murmur; re-examination is required once the fever has subsided in order to confirm.
Young children (≈ 3 years)	The heart rate is fast (100–120 beats/min), so auscultation should be prolonged appropriately; if cooperation is poor, the child may be held in a parent’s arms.
Overweight children	Heart sounds and murmurs may be attenuated; greater pressure should be applied with the stethoscope and, if necessary, the child should sit leaning forward.

Chapter 5 On-Site Quality Control

4.6 Limitations of Auscultation

> **The "forbidden zone" of auscultation — limitations that must be squarely faced**

No murmur on auscultation ≠ a normal heart!

The types of CHD most easily missed:

- Small atrial septal defect (ASD) — the murmur is extremely faint or even absent.
- Small patent ductus arteriosus (PDA) — the murmur is inconspicuous.
- Some cases of pulmonary valve stenosis (PS) — the murmur is soft.
- Rare conditions such as anomalous origin of the coronary arteries.

4.7 Common Interfering Factors in Auscultation

What is interfering with you? — Recognition of common artifactual sounds

Interfering Factor	Character of the Artefact	Remedy
Friction from clothing	Irregular rustling sound	Expose the skin / smooth the clothing flat
Friction between chestpiece and skin	Sharp grating sound	Press the chestpiece lightly and reduce sliding
Friction between tubing and clothing	Low-frequency rustling sound	Secure the tubing
Muscle tremor	Low-frequency vibratory sound	Reassure the child and keep them warm
Ambient noise	Various irregular noises	Turn away from the sound source / press the ear-tips in
Breath sounds	Cyclical breath sounds	Ask the child to hold their breath
Crying	High-frequency irregular noise	Soothe the child, have the parent hold them / listen again later

5.1 Core Principles of Quality Control

The core instrument of on-site quality control is the **spot-check re-verification by echocardiography** — among children who have already completed auscultation (interpreted as negative), a random subset is selected for echocardiographic examination in order to verify the accuracy of the auscultatory conclusion and to detect and correct possible missed diagnoses in a timely manner.

5.2 Spot-Check Methods

(1) Frequency and scale of spot checks

- At least one spot check must be completed on each screening day.
- If several schools are screened on a single day, at least one spot check must be completed at each school.

(2) Sampling rules

Rule	Explanation
The class is the sampling unit	One complete class is drawn each time, and all children in that class undergo echocardiographic re-verification (rather than selecting individual children).
A different age group is spot-checked on each occasion	The classes spot-checked on consecutive screening days must come from different age groups. Example: a 6-year-old class on Day 1 → a 10-year-old class on Day 2 → a 14-year-old class on Day 3 → a 4-year-old class on Day 4, alternating in rotation.
All age groups must be covered	Within one screening cycle (usually 1–2 weeks), all age groups at that screening site must be covered (recommended minimum coverage: pre-school group, 3–6 years; lower-grade group, 7–9 years; middle-grade group, 10–12 years; upper-grade group, 13–18 years).
Give priority to classes that have completed auscultation	The class selected for spot checking must be one that has already completed auscultation on that day.

(3) Spot-check procedure

In the course of the day's screening, the quality-control officer carries out the following steps:

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Step 1: From among the classes that have completed auscultation, select one age group not yet spot-checked
    ├── Review the day's age-group spot-check record sheet
    └── Determine the target age group for this spot check

Step 2: Select one complete class at random from that age group
    ├── Exclude classes that have already undergone echocardiographic re-verification
    └── If an age group has only one class, that class must be selected

Step 3: All children in the class proceed to the echocardiography examination area
    ├── The ultrasound physician is unaware of the auscultation results (single-blind)
    └── Standard-view echocardiography is performed on each child in turn

Step 4: Compare the auscultation results with the echocardiographic results
    ├── Record every case of "auscultation negative + echocardiography negative" (correct exclusion)
    ├── Record every case of "auscultation negative + echocardiography positive" (missed diagnosis; trace the cause immediately)
    └── Calculate the negative-consistency rate for that class

Step 5: Complete the On-Site Auscultation Quality Spot-Check Record Sheet (see Appendix A)
    └── Countersigned by the quality-control officer and the ultrasound physician
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5.3 Handling of Spot-Check Results

(1) Calculation of consistency

```
Class negative-consistency rate =
    number of children negative on auscultation AND negative on echocardiography
    ÷ total number of children in the class undergoing echocardiographic re-verification × 100%

Overall consistency rate for the day =
    sum of "auscultation negative + echocardiography negative" children across all spot-checked
classes
    ÷ sum of the totals undergoing echocardiographic re-verification across all spot-checked classes
× 100%
```

(2) Criteria for judgement and the actions taken

Class Consistency Rate	Judgement	Action
≥ 90%	Excellent	Proceed as normal.
80% – 90%	Qualified	Proceed as normal; record the details of missed cases and report them at that day's handover meeting.
< 85%	Warning	① Trace the source of every missed case immediately (auscultating physician / auscultation conditions / cooperation of the child); ② add one additional class to that day's spot check; ③ the auscultating physician receives targeted feedback from the quality-control officer.
< 80%	Unqualified	① The auscultating physician is suspended from auscultation duties; ② of all the children examined that day by that physician, ≥ 20% are selected for echocardiographic re-verification; ③ the physician must undergo re-assessment within 3 days.

(3) Missed CCHD cases (zero tolerance)

If a missed CCHD case is found in any spot check (that is, auscultation negative but echocardiography confirms critical congenital heart disease):

- The auscultating physician's certification is suspended with immediate effect.
- All of that physician's auscultation records for that day and for the preceding day are reviewed retrospectively, and every relevant child is scheduled for echocardiographic re-verification.
- A root-cause analysis (RCA) is initiated and a written report is produced.
- The physician must repeat the full training programme and pass the assessment before certification can be restored.

5.4 Recording and Reporting of Quality Data

(1) On-Site Auscultation Quality Spot-Check Record Sheet (see Appendix A)

(2) Monthly quality-control summary

At the end of each month the following indicators are compiled and reported to the quality-control centre:

Indicator	Method of Calculation
Number of classes spot-checked in the month	Total number of classes spot-checked across all screening days in that month.

Indicator	Method of Calculation
Number of children spot-checked in the month	Total number of children in all classes spot-checked in that month.
Monthly negative-consistency rate	Number of children “auscultation negative and echocardiography negative” in all spot checks in the month ÷ total number of children spot-checked in the month.
Monthly missed-diagnosis rate	Number of children “auscultation negative but echocardiography positive” in the spot checks in the month ÷ total number of children spot-checked in the month.
Number of missed CCHD events	Total number of missed CCHD cases in that month.
Completeness of age-group coverage	Number of age groups covered in the month ÷ number of age groups that should be covered.

(3) Quarterly quality-control report

A *Quarterly Report on On-Site Quality Control of Cardiac Auscultation* is produced each quarter; its contents include:

- Trend charts of individual consistency for each auscultating physician.
- Analysis of differences in auscultation consistency between age groups.
- Classification and root-cause analysis of missed cases.
- The implementation status of quality-improvement measures.

Appendices

Appendix A On-Site Auscultation Quality Spot-Check Record Sheet

Field	Content
Screening date	_____ year _____ month _____ day
Name of screening site	
Class spot-checked	Grade _____ Class _____
Age group	☐ 3–6 years ☐ 7–9 years ☐ 10–12 years ☐ 13–18 years
Name of auscultating physician	
Name of ultrasound physician	
Total number of children in the class	_____
Auscultation negative + echocardiography negative	_____
Auscultation negative + echocardiography positive (missed diagnosis)	_____
Details of missed case(s)	Name: _____ Age: _____ Echocardiographic diagnosis: _____
Class negative-consistency rate	_____ %
Missed CCHD case?	☐ Yes (activate the emergency procedure immediately) ☐ No
Signature of quality-control officer	_____
Signature of ultrasound physician	_____

Appendix B Age-Group Spot-Check Rotation Schedule (Example)

Screening Day	Target Age Group	Class Spot-Checked
Day 1	Pre-school group (3–6 years)	Kindergarten, senior class
Day 2	Lower-grade group (7–9 years)	Grade 2, Class 1
Day 3	Middle-grade group (10–12 years)	Grade 5, Class 2
Day 4	Upper-grade group (13–18 years)	Junior secondary Year 2, Class 3
Day 5	Pre-school group (3–6 years)	Kindergarten, middle class
Day 6	Lower-grade group (7–9 years)	Grade 3, Class 1
…	…	…

Rotation principle: one complete class from a different age group is spot-checked on each occasion, so that all age groups are covered within a single screening cycle.

> **Preparation note.** This SOP was developed on the basis of the *National Health Commission Protocol for Neonatal Screening for Congenital Heart Disease* (dual-indicator method), the 2025 primary-level expert consensus, and eight years of practical screening experience involving more than 6.3 million children in Yunnan Province. The standards for auscultation training and assessment,

> and the mechanism of echocardiographic spot-check verification for on-site quality control, are all drawn from those eight years of practice.

Translator's note. This document is an English rendering of the Chinese discussion draft "儿童先天性心脏病心脏听诊标准化操作规程（讨论稿）". Section numbering follows the source document exactly, including the items numbered 4.6 and 4.7 that appear under Chapter 5; a sentence fragment at the end of the source preparation note has been rendered as far as it is legible. The figure in Section 4.2 has been redrawn in English from the original Chinese diagram.